Due to 1/2/2020

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Data acquisition

EE 463 (1) 18/11/2019

to Transfer information from Tranducer to Controler by changing The electrical signal to Digital.

1- RTD → PT 100 → Transducer for Temp can read [0 ~ 139 Ω]

@ 0°C = 100 Ω , [0.39 Ω/C°]

Ex: @ 23°C ⇒ 100 + (23 × 0.39) = 108.97 Ω

	TTL		CMOS	
	0	1	0	1
	off	on	off	on
	0 volt	5 volt	0 volt	(3 ~ 18) volt
in →	(0 ~ 0.8) V	(2 ~ 5.5) V		
out →	(0 ~ 0.5) V	(4.9) V		

* [illegible] (range [illegible]

* 137 Ω what's The temp. 137 Ω − 100 Ω = 37 Ω

$T = 37\,\Omega \,/\, 0.39\,\frac{\Omega}{C°} = 94.87\,C°$

→ Data acquisition: is The process by which physical phenomena from The real world are Transformed into electrical signals That are measured & Converted into digital format for processing analysis & Storage by a Computer.

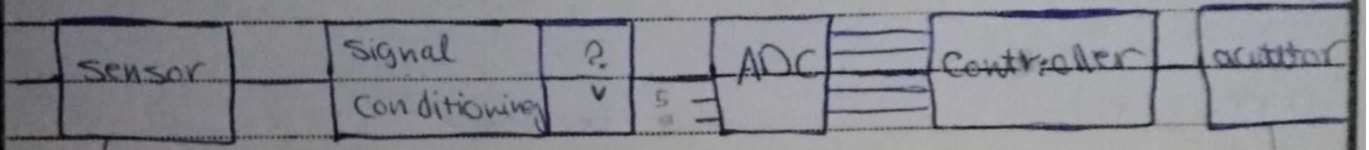
2- LM 35 → Tranducer for measure Temp.

(0 ~ 100°C) 10 mV/C° [0 ~ 1 V]

AgiP آجيب	INTERNAL NOTES	Date	N 2
FROM 21/11/2019	TO EE462		Your Ref / Our Ref

Subject

حركة
حرارة
وزن



↳ V, A, R, pulse, phase, watt, charge.

Fundamentals of Data ecquisition

Sensor.

Field wiring.

تهيئة الإشارة ← Signal Conditioning ▸ filtering, Amplification, isolation, linearization, Ex

Data ecquisition hardware ▸ عدد المداخل مهم ، يعتمد على تطبيق مطلوب

Controller (operating System) ▸ Arduino, PC ,الخ

Data ecquisition software.

7805 → 5V , 7812 → , 7905 → -5V , 7912 → -

↳ Voltage Regulation

\- Real Time Operating System ▸ يعطي أو يقدم الخدمات الآن (فوري)

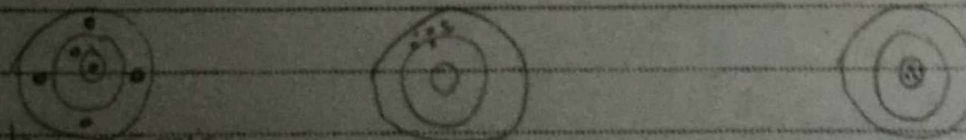
25/11/2019 EE463 (3)

* Accuracy ▸ تعريف - مدى صحة قراءة الجهاز

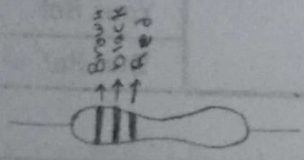
وعندما نقيس نقاس بنسبة الخطأ في الجهاز

Measurment Uncertainty - اسم آخر

* precision / Repeatability / Reproducibility ▸

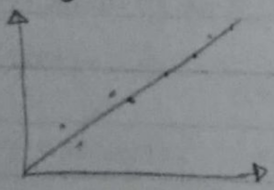


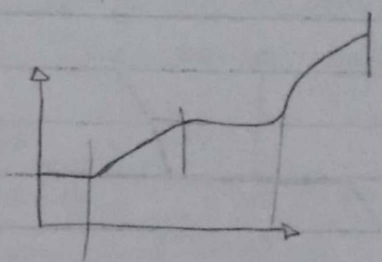
low Precision low accuracy | High Precision low Accuracy | High accuracy High precision



Resistor (800Ω ~ 1200Ω)

★ linearity ▸





- LM35 10mV/C°
- RTD @0C° 100Ω 0.39Ω/C°

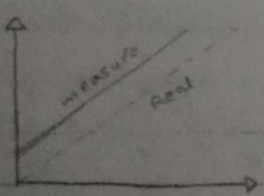
Example ▸

	R(Ω)	Temp (C°)
	307	200
✓ $\boxed{0.23\Omega/C^\circ}$?!	314	230
$R_{T=0} = 261\Omega$	321	260
	328	290

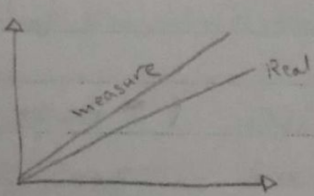
★ كل 30° ← 7Ω

★ لما T=0°C ⇐ R=260.3Ω

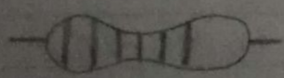
- $\frac{200}{30} = 6.67$ $7 \times 6.67 = 46.67$ $307 - 46.67 = 260.3\Omega$



Bias zero drift



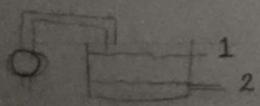
Sensitivity drift



→ كل شريط الأول يعين قراءات و آخر واحد الـ accuracy "Read it"

و ... الأخير Temp coefficient.

Hastreycess



- حتى لما يوصل لمستوى معين توقف الملحقة عند المستوى (2)، أخذ مستويين مختلفين.

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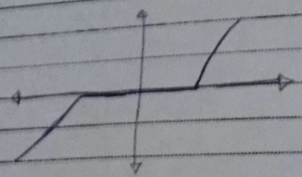
TO | Your Ref | Our Ref

FROM

Subject



* Reslution ►

28 / NOV / 2019 EE463 (4)

- Range ► مدى $(0 \sim 100)$
  Span ► طول المدى $(\cancel{0} \sim 100) = 100 - 0$
- Range ► $-20 \sim 120$
  Span ► $(120) - (-20) = 140°$

Signal Conditioning ►

RTD ► PT100 $(100\Omega + \overset{T}{100} \times 0.39 \frac{\Omega}{C°})$

$@\ 0°C = 100\Omega$ • SenSitivity $= 0.39\ \Omega/C°$

EX ► $(0 \sim 100°C)$ Temp range

$(100\Omega + (0°C \times 0.39 \frac{\Omega}{C°}) \sim (100\Omega + (100°C \times 0.39\ \Omega/C°)$

$(100\Omega \sim 139\Omega)$ #

EX ► $(-20°C \sim 120°C)$

$(100\Omega + -20° \times 0.39 \frac{\Omega}{C°}) \sim (100\Omega + 120 \times 0.39 \frac{\Omega}{C°})$

$(92.2\Omega \sim 146.8\Omega)$ #

[4]

LM35 , sensitivity $= 10\ mV/c^\circ$

Temp range $(0 \sim 100^\circ C)$, Sensor o/p range $(0v \sim 1v$

EX ▶

accelerometer range $(\pm 20g)$, & @ $0g = 5ma$

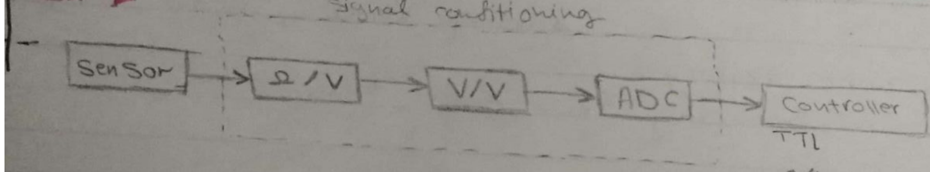
Sensitivity $= 0.115\ mA/g$, calculate The sensor output range ?

accelerometer range $(-20g \sim 20g)$

accelerometer range o/p ▶ $(5 + -20 \times 0.115) \sim (5 + 20 \times 0.115)$

$(2.7ma \sim 7.3ma)$ #

EX ▶

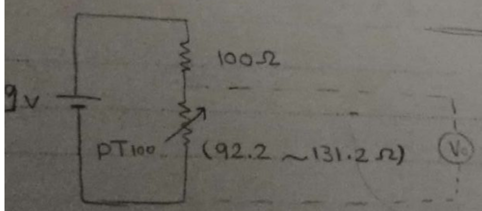


PT100 ▶ range $(-20 \sim 80^\circ C)$

Sensor o/p range ▶ $\left[\left(-20^\circ C \times 0.39 \frac{\Omega}{c^\circ}\right) + 100\right] \sim \left[\left(80^\circ C \times 0.39 \frac{\Omega}{c^\circ}\right) + 100\right]$

$(92.2\ \Omega \sim 131.2\ \Omega)$

* Single Ended



Voltage devider

@ $-20^\circ C$

$V_o = 9V \times \frac{92.2}{92.2 + 100} = 4.317V$

@ $80^\circ C$

$V_o = 9V \times \frac{131.2}{131.2 + 100} = 5.107\ V$

Sensor output range in Voltage $(4.317\ V \sim 5.107\ v)$

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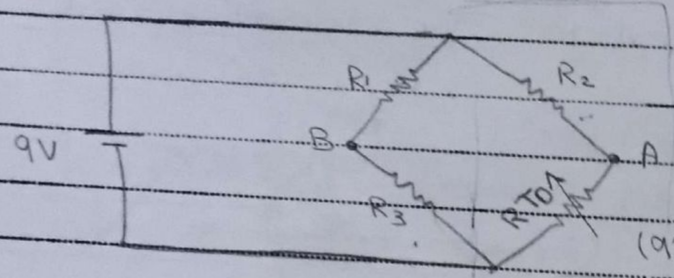
FROM	TO	Your Ref	
		Our Ref	

Subject $R_1 = 120\Omega$, $R_2 = 130\Omega$, R_3 = Calculate using ⊛

"منظرة"



wheston

◄ voltage devider عن bridge ميزة ال

1- more accuracy.

2- Start measuring from Zero. "best"

$R_4 * R_1 = R_2 * R_3$ ⊛

$92.2 * 120 = 130 * R_3 \longrightarrow R_3 = 85.107\,\Omega$

صفري

$$V_A = 9 \times \frac{92.2}{92.2 + 130} = V_S \times \frac{R_4}{R_4 + R_2} = 3.734\ V$$

$$V_B = V_S \times \frac{R_3}{R_3 + R_1} = 9 \times \frac{85.107}{85.107 + 120} = 3.734\ V$$

$\Delta V = V_A - V_B = 0\ V$

كبرى

$V_B = 3.734\ V$

$$V_A = 9 \times \frac{131.2}{131.2 + 130} = 4.52\ V$$

$\Delta V = V_A - V_B = -0.7866\ V$

Bridge O/P Range $(0 \sim 0.786\ V)$ #

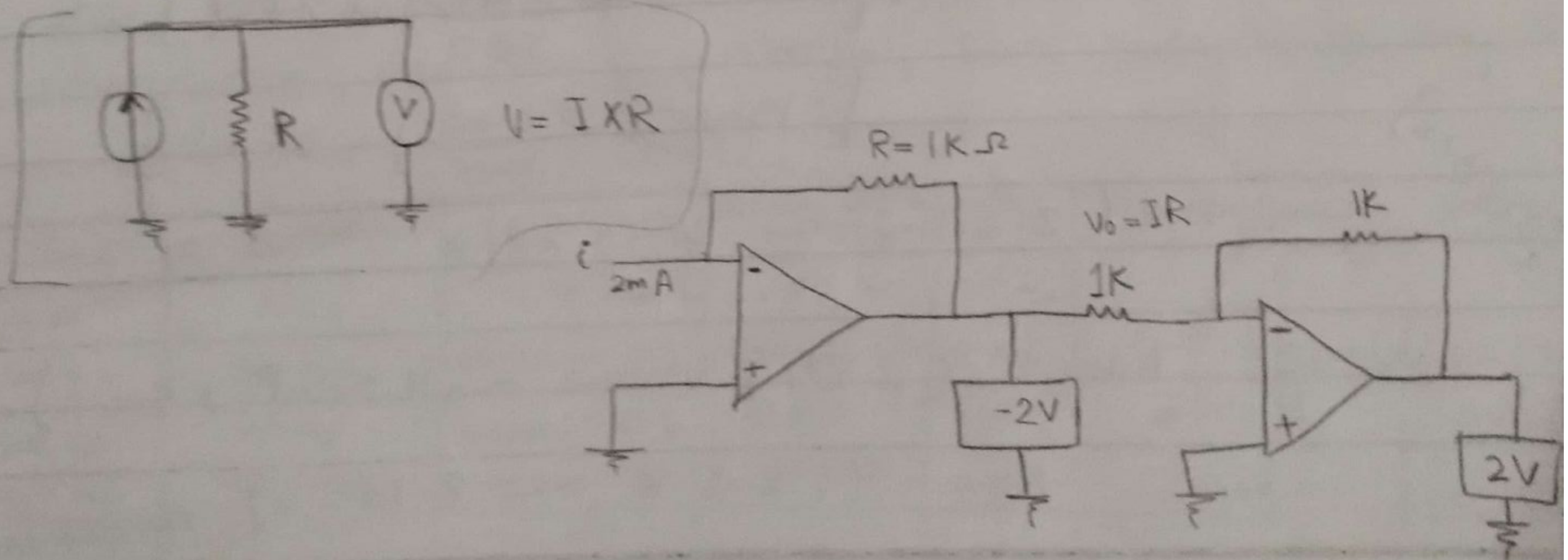
$$4.254 = 4 \times \frac{}{RTD + 130\,\Omega}$$

$$\frac{110\,\Omega - 100\,\Omega}{0.39\,\Omega/C^\circ} = 39.69\,C^\circ \quad \#$$

(5) EE463 2/12/2019

EX ▶

pressure sensor Sensitivity 0.12mA/bar working in the Range (0 ~ 40 bar), calculate the sensor output Ra



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FROM | TO | Your Ref | Our Ref

Subject

$0 \sim 40$ bar

0×0.12 mA $\sim 40 \times 0.12$ mA

$(0 \sim 4.8$ mA$)$

using Resistance $R = 1k\Omega$

$(0 \sim 4.8mA \times 1k\Omega)$

$0 \sim 4.8V$ #

8 EX ▶

Pressure sensor sensitivity 0.11 mA/bar & @ Ø bar = 27 mA, working in the Range (1 ~ 15 bar). Calculate the sensor output Range and convert it to Voltage using R = 500 Ω, calculate the Voltage Range.

Pressure Range (1 ~ 15 bar)

Sensor output Range $\left[\left(1bar \times \frac{0.11\,mA}{bar}\right) + 27mA\right] \sim$

$\left[\left(15bar \times \frac{0.11\,mA}{bar}\right) + 27mA\right]$

$(2.81\,mA \sim 4.35\,mA)$ ✗

$(27.11 \sim 28.65)$ ✓

Voltage Range $(2.81mA \times 500\Omega \sim 4.35mA \times 500\Omega)$

$(1.405\,V \sim 2.175\,V)$ #✗

$(13.555\,V \sim 14.325\,V)$ ✓

9 EX ▶

LM35 : Temp sensor working in The Range (0~100°c) with Sensitivity 10mV / C°, calculate The output sensor in The Range (25 ~40°c)

$$\left(25^{\circ}C \times \frac{10mV}{C^{\circ}}\right) \sim \left(40^{\circ}c \times \frac{10\,mV}{C^{\circ}}\right)$$

$$(250\ mV \sim 400\ mV)$$

accelerometer	MS1002	MS1005	MS1010	unit
Full Scale acceleration	±2	±5	±10	g
Scale factor sensitivety	1350	540	270	mV/g

$$V[t] = V[t-1] + \left((A[t] + A[t-1]) * \frac{T}{2}\right)$$

interval

$$Pos[t] = Pos[t-1] + \left((V[t] + V[t-1]) * \frac{T}{2}\right)$$

10 EX ▶

using The accelerometer MS1010, calculate The accelaration, velocity, position, for each following Reading

interval = 100 ms

A[t] velocity

	Time	acc output (mV)	accelatation (g)	accelaration (m/s²)	V[t] m/s	Displacement (m)	Position (m)
t0	0	0	0	0	0	0	0
t1	100 ms	200 mV	200/270 = 0.74 g	0.74×9.81 = 7.26	0.363	0.018 m	0.018 m
t2	200 ms	500 mV	500/270 = 1.85 g	18.167	1.634	0.118 m	0.118 m
t3	300 ms	470 mV	470/270 = 1.74 g	17.07	3.395	0.218 m	0.218 m
t	400 ms	200 mV					
		0 mV	0 g	0			
		−120 mV	−0.44 g	−4.36			

[9]

AgiP آجيب	INTERNAL NOTES	Date	N
FROM	TO		Your Ref / Our Ref

Subject $V[t] = V[t-1] + (A(t) + A(t-1)) * \frac{T}{2})$

from (*) $t = 200$ ms

$V[t] = 0.363 + (18.167 + 7.26) 50 \times 10^{-3} = 1.634$ m/s

$Pos[t] = 0.018 + (1.634 + 0.363) 50 \times 10^{-3} = 0.118$

$t = 300$ms

$V[t] = 1.634 + (17.07 + 18.167) 50 \times 10^{-3} = 3.395$ m/s

$Pos[t] = 0.118 + (3.395 + 1.634) 50 \times 10^{-3} = 0.36945$?!

$t =$

what's The sensor output Range?

sensor acc range $(-10g \sim +10g)$

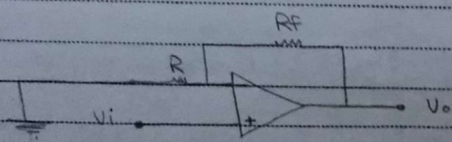
" o/p " $\left[\left(-10g \times \frac{270 mv}{g}\right) \sim \left(10g \times \frac{270 mv}{g}\right)\right]$

$(-2.7v \sim 2.7v)$

4/12/2019 EE463 (6)

operational Amplifier: OP - AMP

1. non-inverting Amp



$V_o = \left(\frac{R_f}{R} + 1\right) V_i$

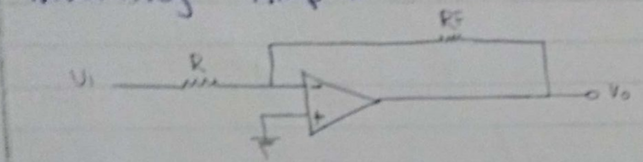
EX ▶

$R = 1K\Omega$, $R_f = 1.5K\Omega$, $V_i = 1.75V$, $V_o = 4.375$ #

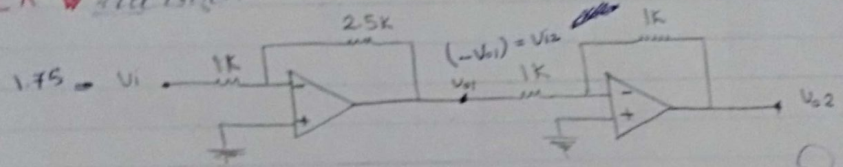
Same fig above

2) Inverting Amp ▶

$\boxed{V_o = -\frac{R_f}{R} \times V_i}$?!



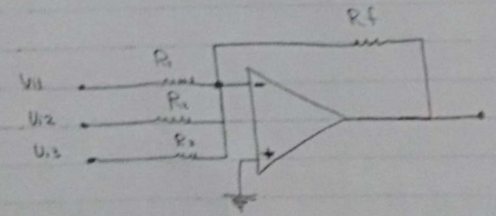
12 EX ▶

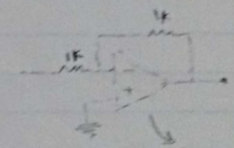


$V_{o1} = -4.375$, $V_{o2} = 4.375$ #

?

3. Addition ▶





بس يقلب الإشارة

$$V_o = -\left(\frac{R_f}{R_1} V_{i1} + \frac{R_f}{R_2} V_{i2} + \dots + \frac{R_f}{R_n} V_{in}\right)$$

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INTERNAL NOTES | Date | N

FROM | TO | Your Ref / Our Ref

Subject

Ex ▶ $R_f = 2.5\,K\Omega$, $R_1 = R_2 = R_3 = 1\,K\Omega$

$V_1 = 1.25\,v$, $V_2 = 0.75\,v$, $V_3 = 2\,v$, $V_o = ?$

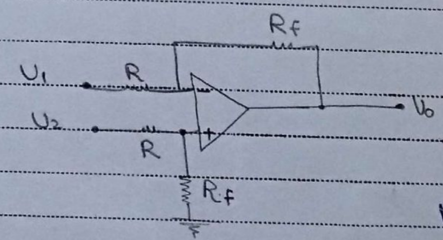
$V_o = 2.5\,(1.25 + 0.75 + 2) = 10\,V$

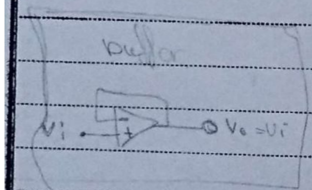
Ex ▶ find $2V_1 + 3V_2 + \frac{1}{4}V_3 = ?$

Ex ▶ what's The average of The inputs ?

$\frac{1.25 + 0.75 + 2}{3} = -$ #

Subtructor ▶



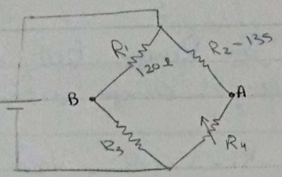


$V_o = -\frac{R_f}{R}(V_1 - V_2)$

$V_o = \frac{R_f}{R}(V_2 - V_1)$

Ex ▶

RTD PT100 in The Range (20°c ~ 90°c) , using whenstone bridge , design circuit to which $R_1 = 120$, $R_2 = 135$, $V_s = 12\,V$, calculate the o/P voltage range from The bridge.



Temp Range = (20°c ~ 90°c)

Resistance Range $[100+(20\times0.39)] \sim [100+(90\times0.39)]$

$(107.8\ \Omega \sim 135.1\ \Omega)$ #

$R_4 R_1 = R_3 R_2$

$R_3 = \frac{R_4 R_1}{R_2} = \frac{107.8 \times 120}{135} = 95.82\ \Omega$ #

$V_A = V_s \frac{R_4}{R_4 + R_2} = 5.3278\ V$ #

$\Delta V = V_A - V_B = 0$ ✓

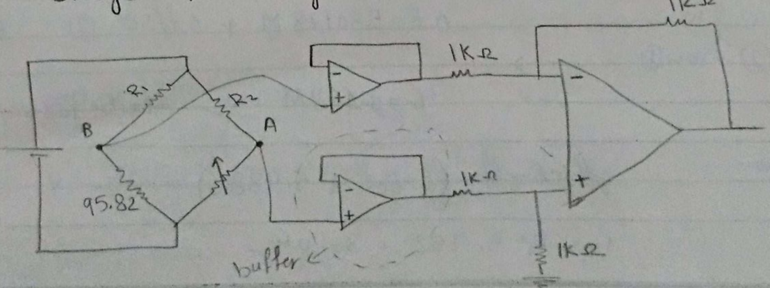
$V_B = V_s \frac{R_3}{R_3 + R_1} = 5.3278\ V$ #

@ 90°c

$V_A = 12 \frac{135.1}{135.1 + 135} = 6.0622\ V$

$\Delta V = V_A - V_B = 0.67442\ V$

bridge O/P Range $(0 \sim 0.67442\ V)$



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AgiP آجيب	INTERNAL NOTES	Date	N

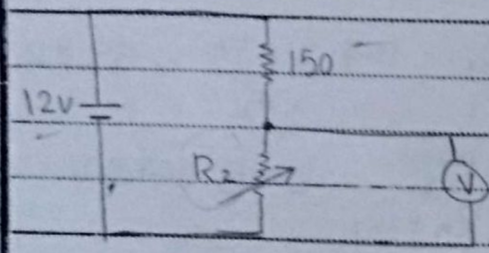
FROM	TO	Your Ref / Our Ref

Subject

EX ▶ using RTD PT100 in The Range (20°C ~ 90°C) design circuit to set o/p Voltage range (0 ~ 4 V)?

using Voltage devider with $R_1 = 150\,\Omega$, $V_s = 12\,V$

RTD range ($107.81\,\Omega \sim 135.1\,\Omega$)



@ 20°C

$$V_o = 12 \times \frac{107.81}{107.81+150} = 5.018\,V$$

@ 90°C

$$V_o = 12 \times \frac{135.1}{135.1+150} = 5.686\,V$$

o/p range (5.018 v ~ 5.686 v)

$V_o = V_i M + \text{offset}$

$4 = 5.686\,M + \text{offset}$ ①

$0 = 5.0178\,M + \text{offset}$ ②

subtract ② from ① →

$4 = 0.668\,M \Rightarrow M = 5.98802$

$\text{offset} = 4 - (5.686 * 5.98802) = -30.04$

$V_o = V_i \cdot 5.982 - 30.04$

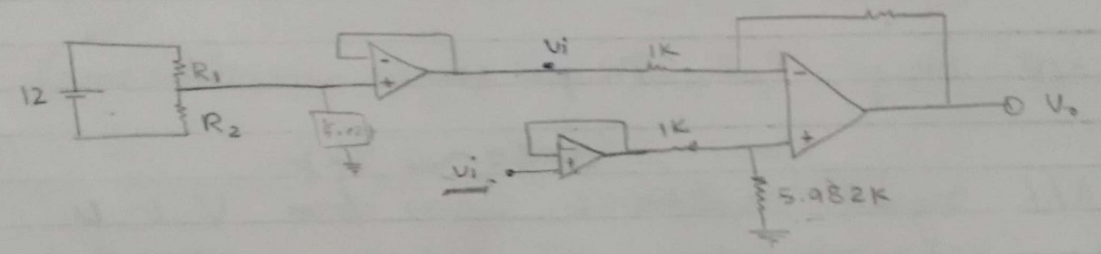
* لما نحط ال sensor R(Ω) ونبي نحوله ل V(v) نشغل voltage Divider bridge

* op-Amp " " " I(A) " "

5.982 (Vi - 5.021)

Vi	5.0178	5.3519	5.686
Vo	0	2	4
	0.00007	1.9762	3.973

→ للتحقق



9/Dec/2019 EE463 (7)

Ex ▸ pressure Sensor Sensitivity 1.1mA/bar in The Range (2~18 bar) & @ 0 bar = 8.2 mA Design Signal Conditioning Circuit for ADC which Voltage Reference (0~3V) ?

(2 ~ 18 bar) → Pressure Range

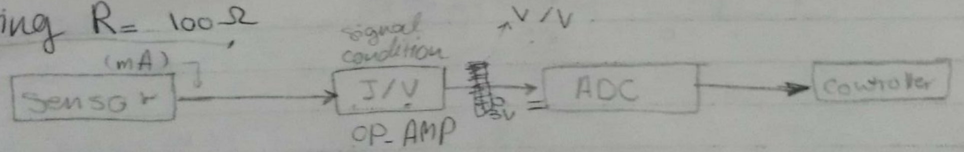
(8.2 + [1.1×2] ~ 8.2 + [1.1×18]) → Sensor O/P Range

(10.4 mA ~ 28 mA)

∴ نطرح 8.2mA → 2bar لأنه @ 2 bar = 8.2mA *

[ركزي ع الحساب]

→ using R = 100 Ω ,



→ For Conversion to Volt

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INTERNAL NOTES

Date

N

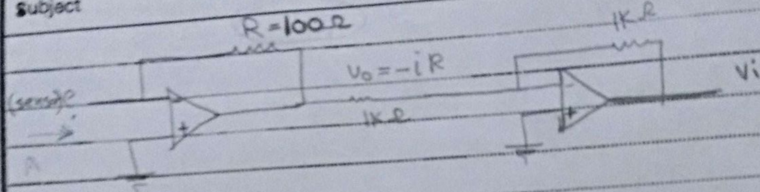
Your Ref

Our Ref

TO

FROM

Subject



o/p Voltage Range (10.4 mA × 100 Ω ~ 28 mA × 100 Ω)

(1.04 V ~ 2.8 V)

* Add signal condition to convert from V to V

$V_o = V_i \cdot M + \text{offset}$

$3 = 2.8M + \text{offset}$ $\boxed{1}$

$0 = 1.04M + \text{offset}$ $\boxed{2}$

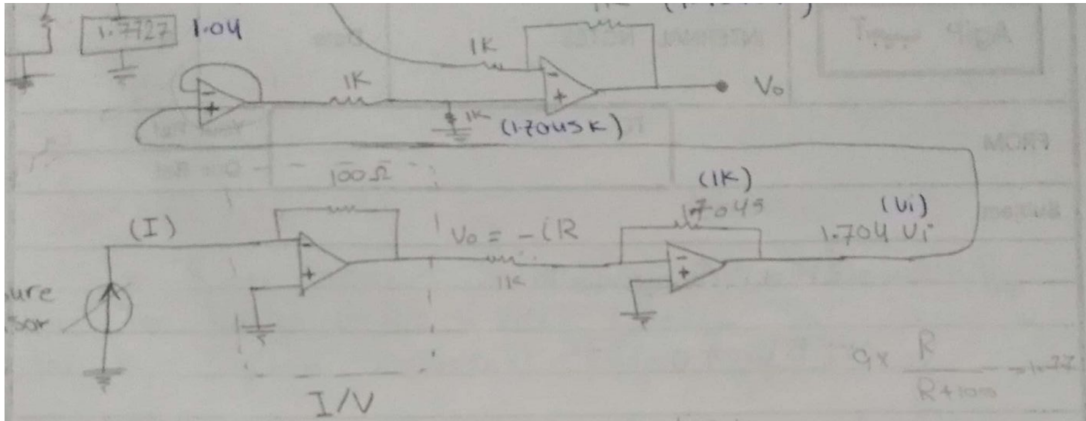
$3 = 1.76M$ $\boxed{1-2}$

$M = 1.7045$

$\text{offset} = -1.04 * 1.7045 = 1.7727$

$V_o = V_i \, 1.7045 - 1.7727$

Vi	1.04	1.92	2.8
Vo	-0.00002	1.49994	2.9999
	0	1.5	3



number in

when you change eq The fig change

$$eq \rightarrow \boxed{V_o = 1.7045(V_i - 1.04)}$$

$V_o = 1.7045\, V_i - 1.772$

EX ▶ pressure sensor sensitivity 12mV/bar in The Range (0 ~ 20bar) & @ 0 bar = -15mV
Design signal conditioning cct for ADC which Voltage Reference (0 ~ 3V)

pressure Range (0 bar ~ 20bar)

sensor o/p Range $\left(-15mV + (0 \times 12\frac{mv}{bar}) \sim -15mv + (20 \times 12)\right)$

$(-15mV \sim 225mV)$

no need for convert it is already Voltage o/p

$V_o = V_i M + offset$

$3 = 0.225 M + offset$ (1)

$0 = -0.015 M + offset$ (2)

$3 = 0.24 M \Rightarrow M = 12.5$

0.1875

AgiP آجيب	INTERNAL NOTES	Date	N
FROM	TO	Your Ref / Our Ref	

Subject

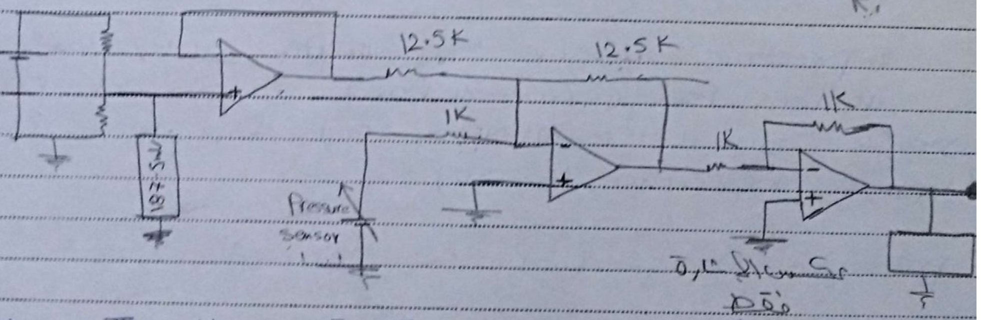
off set $= 0.015 * 12.5 = 0.1875\,V$

$V_o = 12.5 V_i + 0.1875$

V_i	$-15mV$	$105mV$	$225mV$
V_o	0	1.5	3

100% accuracy.

$V_o = \frac{R_f}{R_1}(V_i)$



what is The Value of The pressure if The O/P Voltage IS 1.2 V ? (8 bar)

what is The O/P Voltage if The pressure is 7 bar ? (1,05 V)

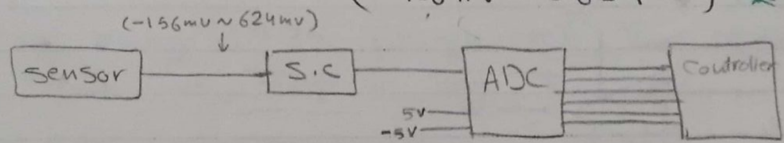
2019/Dec/12. EE463 (8)

EX ▸ Temp Sensor Sensitivity (7.8 mv/C) working in The Range ($-20^\circ C \sim 80^\circ C$), Design S.C (signal condition) circuit for ADC wich Reference range ($\pm 5V$)

Temp Range ($-20^\circ C \sim 80^\circ C$)

Sensor O/P range ($-20 \times 7.8 \frac{mv}{C^\circ} \sim 80 \times 7.8 \frac{mv}{C^\circ}$)

($-156\ mv \sim 624\ mv$) #



$$V_o = V_i M + offset$$

$$5 = 624 \times 10^{-3} M + offset \rightarrow \boxed{1}$$

$$-5 = -156 \times 10^{-3} M + offset \rightarrow \boxed{2}$$

$$10 = 0.78 M \rightarrow \boxed{1-2}$$

$$M = 12.8205 \#$$

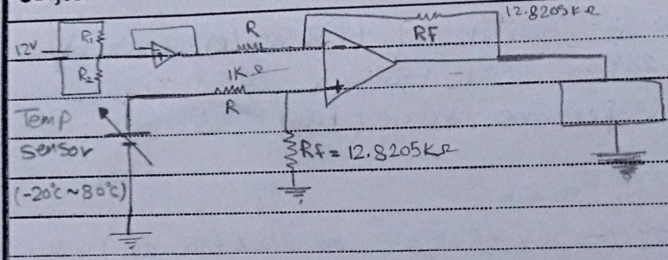
$$offset = 5 - 624 \times 10^{-3} \times 12.8205$$

$$offset = -3 \#$$

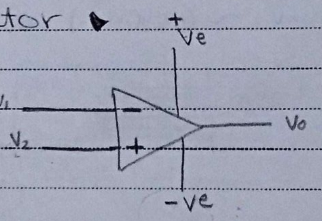
$$V_o = V_i \times 12.8205 - 3 \#$$

V_i	-0.156	0.234	0.624
V_o	-4.999998	-3×10^{-6}	4.999992
	-5	0	5

→ "التحقيق ضروري"



Comparator



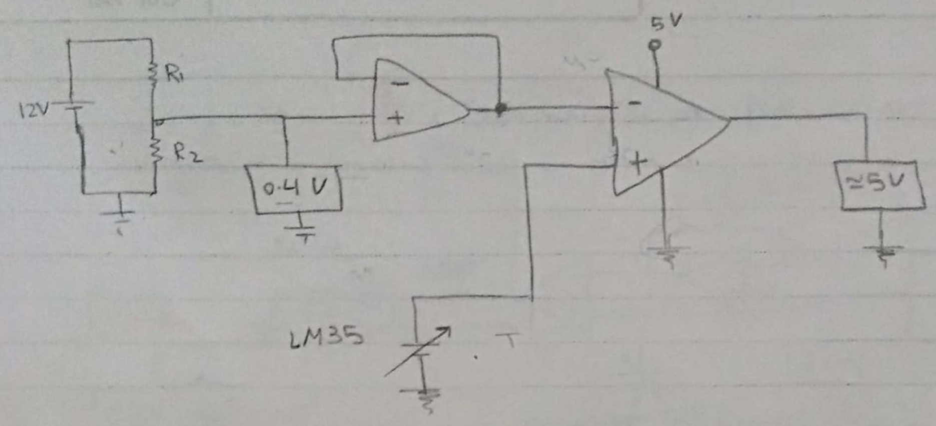
$V_1 > V_2 \Rightarrow V_o = -V_e$

[$V_2 > V_1 \Rightarrow V_o = +V_e$]

2) EX: using LM35 Design CirCuit That operate Fan if The Temp is more Than 40°C.

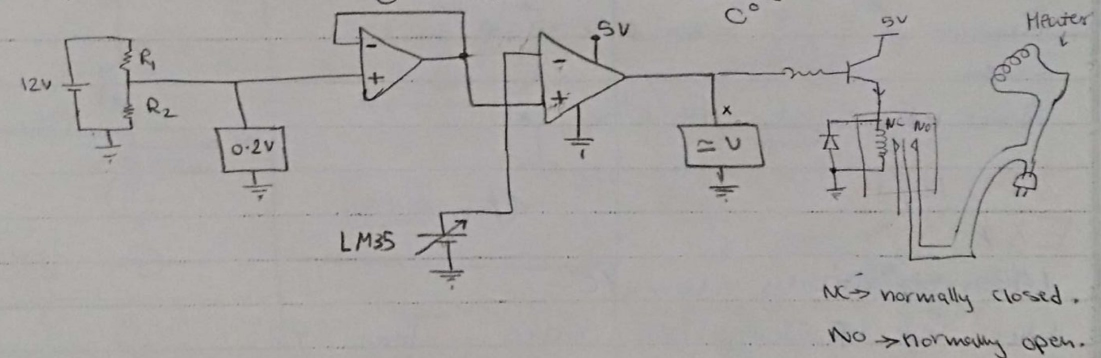
Temp Sensor o/p @ $40°C = 40°C \times \frac{10mv}{C°} = 400mV \simeq 0.4V$

$T > 40°C$



EX ▶ using LM 35 Design cct That operater heater if The Temp is less Than 20°C. $T < 20°$

Temp Sensor O/P @ $20°C = 20°C \times \frac{10mV}{C°} = 200\,mV$



EX ▶ using LM35 Design cct That operate Red led if The Temp is less Than 18°C / blue led if The Temp is more Than 42°C / Green led if The Temp is between (18/ T/ 42°C).

sad Sick

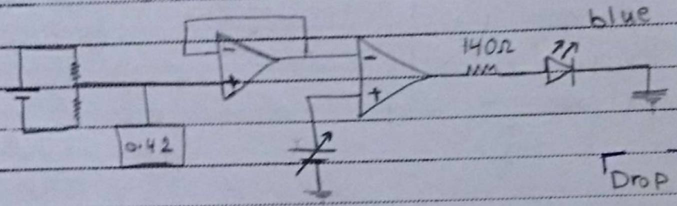
Ques

AgiP آجيب	INTERNAL NOTES	Date	N
FROM	TO		Your Ref / Our Ref

Subject

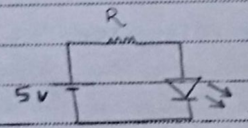
Temp sensor o/p @ 18°c = 18c° x $\frac{10mv}{c°}$ = 180 mV

" " " " 42°c = 42°c x $\frac{10mv}{c°}$ = 420 mV



[Drop on led ▸]

{ Red = 1.8 v }
{ blue = 3.6 V }
[Green = 2.1 V]



20mA = Max → أي شي عشان الإضاءة ‥

$R_{Red led} = \frac{5-1.8}{10mA} = 320\,\Omega \simeq 330\,\Omega$ #

$R_{blue\ led} = \frac{5-3.6}{10mA} = 140\,\Omega$ #

2019/12/15 EE463 (9)

24 EX ▸

LM35, sensitivity = 10mV/C°

blue led if Temp is more Than 42°

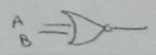
Red " " " " less " 18°

Green " is between.

So, we using NoR Gate if The blue & Red off Green Turn ON.

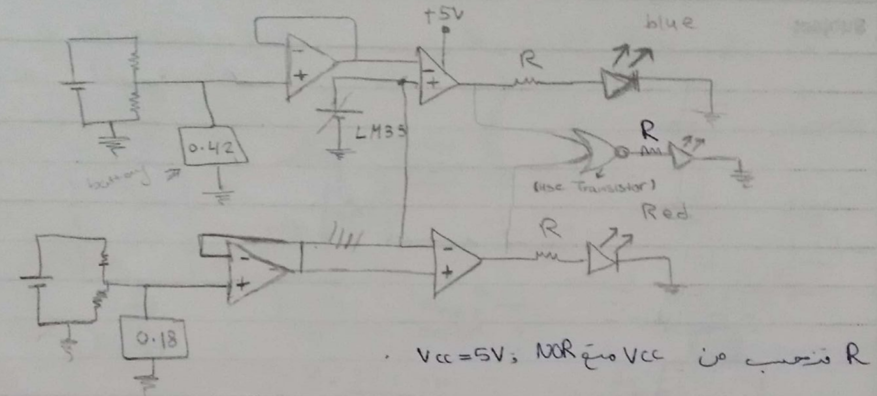
★ Pull up High, untell you give it Zero → NOR (10k, Vcc)

★ " Down , " " " " → OR (10k)

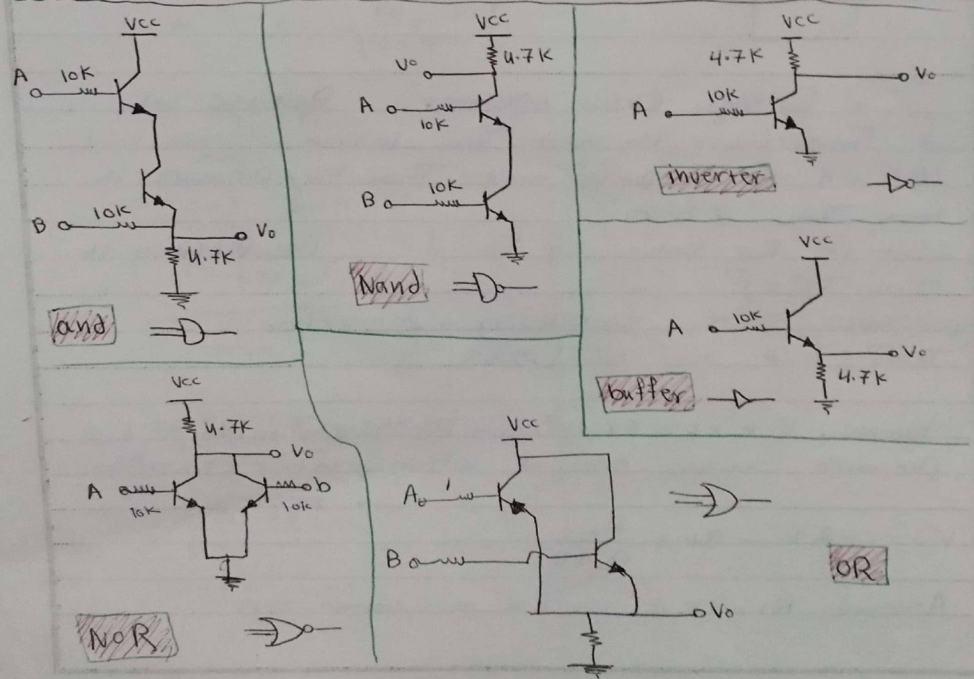
NOR 

A	B	$f = \overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

تحليل الـ Example



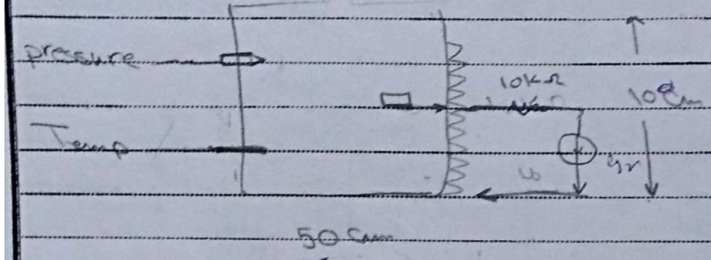
R نحسب من Vcc مع NOR ; Vcc=5V .

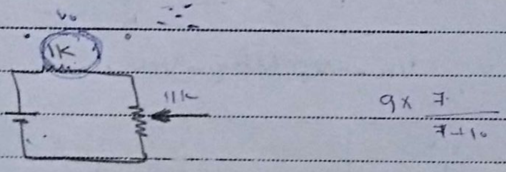


AgiP آجيب | INTERNAL NOTES | Date | N

FROM | TO | Your Ref | Our Ref

Subject





$V_s = 9V$

EX ▸ Design Circuit operator Release Value if The pressure is more Than 10 bar (Release Value) Relive Red led if Temp is more Than 50 / pressure is OR less Than 2 bar.

what is The Value of V_o if is 15L (it is in The Tank)

pressure sensor sensitivity = 20 mV/bar

Temp " is LM35.

Volume $= \pi r^2 \times h = \pi \times (25)^2 \times 100 = 196350\ cm^3 = 196.35\ L$ #

pressure sensor O/P at 10 bar $\rightarrow$ 10 bar $\times 20 \frac{mV}{bar} =$

$\rightarrow$ 200 mV #

$VD = 0.2\,V = 9V \times \frac{R_2}{R_2 + R_1}$

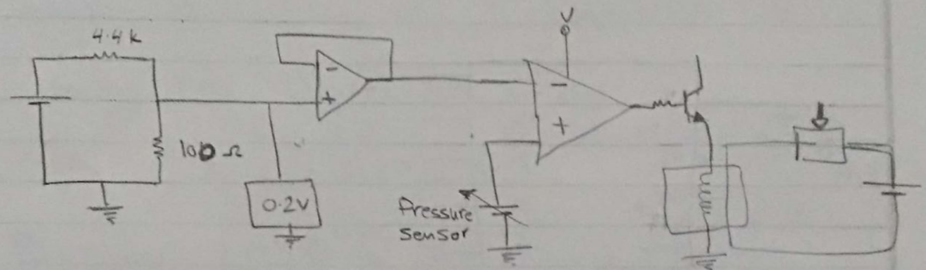
Assume $R_1 = 1k\Omega \rightarrow k\Omega$ less current cost

$\rightarrow$ 2K when 20cm High

$R_2 + R_1 = 11k\Omega$

$0.2 R_2 + (1K * 0.2) = 9V R_2 \rightarrow R_2 = 22.7\,\Omega$ # X

$R_1 = 4.4K \quad R_2 = 100\,\Omega$



$V_0 = 9V \times \dfrac{R_2}{1K + 10K}$ 0.7639 ?!

$\pi r^2 \times h = 1500$ cm³

1000 cm³ $\rightarrow$ 1L

$\boxed{h = 7.639 \text{ cm}}$ 20cm

15L 0.7639 K 2K

$V_0 = \boxed{0.625}$ #

$\boxed{763.9\,\Omega}$

$\dfrac{196.35}{100\text{cm}}$

$V_0 = \dfrac{9 \times 7.639}{11K}$

H > 80cm Led → ON

(±2) Volt

AgiP آجيب

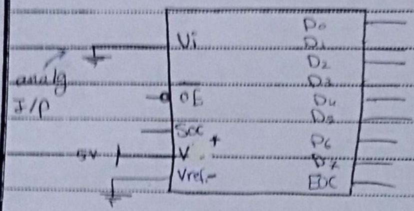
INTERNAL NOTES

Date | N

FROM 2019/12/19 | TO EE463 | Your Ref / Our Ref 10

Subject

Analog to Digital Converter ▶ (ADC)



Unipolar (0~5V) / (-5~0V)

Bipolar (±5V), (±3V)

OE ▶ output Enable
SOC ▶ Start of Conversion
D0~D7 ▶ Digital O/P
EOC ▶ End of Conversion

$$\text{Resolution } (\Delta V) = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^n} = \frac{5}{2^8} = 19.53125 \times 10^{-3}$$

$$\text{Digital O/P} = \frac{\text{analog I/P}}{\Delta V}$$

26 **Ex** ▶ What is the digital o/p, if the I/p is 1.85V ?

$$\text{Digital O/P} = \frac{1.85}{19.53125\times10^{-3}} = 94.72 \simeq 95$$

128	64	32	16	8	4	2	1
0	1	0	1	1	1	1	0

27 EX ▶ what's The analog I/P , if Digital O/P 01011000

$$\text{analog I/P} = \text{Digital o/p} \times \Delta V$$
$$= 88 \times 19.53125\ mV$$
$$= 1.71875\ \#$$

28 EX ▶ using LM35D in The Range ($20 \sim 115°C$) design S.C cct for ($0 \sim 4\ V$) Voltage Reference ADC :

a] what is The digital O/P if The Temp($37°C$, $107°C$)
b] what is Temp if The digital O/P is $(01010101)_2$?

Sensor O/P Range($20 \times 10\frac{mV}{C°} \sim 115 \times 10\frac{mV}{C°}$)

($0.2V \sim 1.15V$)

$V_o = m\ V_{in} + \text{offset}$

$0 = m\ 0.2 + \text{offset}$ ①

$4 = m\ 1.15 + \text{offset}$ ②

②−① $4 = m\ 0.95$

$m = 4.21052$

$\text{offset} = -0.8421$

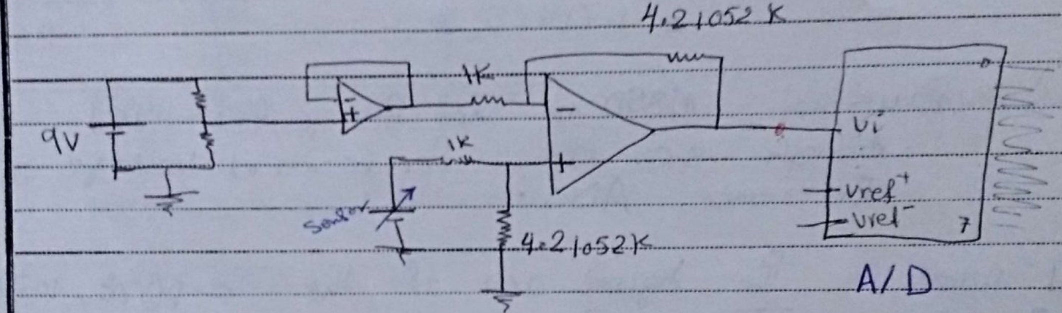
$V_o = 4.21052\ V_i - 0.8421\ \#$

AgiP آجيب	INTERNAL NOTES	Date	N
FROM	TO	Your Ref / Our Ref	

Subject

Vi	0.2	0.675	1.15
Vo	4 μV	2.00005	3.99999
	0	2	4

$V_o = 4.21052\,(V_i - 0.2)$ ✓



$\Delta V = \frac{4\,V}{256} = 0.015625\ V$

Digital o/p $= \frac{\text{analog IP}}{\Delta V}$

@ 37°C

Sensor o/p $= 37°C \times 10 = 370$ mV ✓

$V_o = 4.21052(0.37 - 0.2) = 0.7158$ V

~~ΔV~~ Digital o/p $= \frac{0.7158}{0.015625} = 45.8107 \simeq 45$

$$\begin{array}{cccccccc} 128 & 64 & 32 & \cancel{16} & 8 & 4 & 2 & 1 \\ (0 & 0 & 1 & 0 & 1 & 1 & 0 & 1)_2 \end{array} \quad \#$$

@ $107^\circ C$

Sensor O/P = $107^\circ c \times 10\,mV = 1.07\,V$

$V_o = 4.2105\,(1.07) - 0.8421 = 3.663135\,V$

$D.O = \frac{3.663135}{0.015625} = 234.44 \simeq 234$

$$\begin{array}{cccccccc} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ (1 & 1 & 1 & 0 & 1 & 0 & 1 & 0)_2 \end{array} \quad \#$$

$(01010101)_2 = (85)_{10}$

analog I/P = 1.328125

$1.328125 = 4.2105\,V_i - 0.8421$

$V_i = 0.51543\,V$

$T = 0.51543 / 10\,mV$

$51.54^\circ C$

#

AgiP آجيب	INTERNAL NOTES	Date	N
FROM 23/12/2019	TO EE463	Your Ref 11 / Our Ref	

Subject EX ▸

using Accelormeter which Sensitivity (0.13 mA / g) at 0g = 1.9 mA in The Range (∓ 15g) design Signal Condition cct for ∓ 3V Voltage reference R = 200 Ω.

for digital o/p (unpolar) $= \frac{\text{analog I/P}}{\Delta V}$

$\Delta V = \frac{V_{ref}^{+} - V_{ref}^{-}}{2^n} = 0.02344$

Shift في حالة الناتج بالسالب لازم نغير

input	output
-3	0000 0000
$-3 + \Delta V = -2.9766$	0000 0001
$-3 + 2\Delta V = -2.9331$	0000 0010

1111 1111 → 255 , $2^8 = 255$

EX ▸ analog I/P = 1.5 V

$\frac{1.5 + 3}{23.43 \times 10^{-3}} = 192$

analog i/p = 0 → 256/2 = 128 *

Digital o/P (bipolar) $= \frac{\text{analog I/P} + V_{ref}}{\Delta V}$

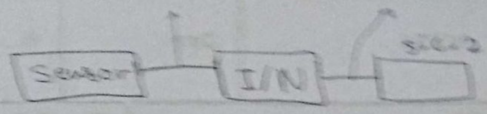
a). what is The digital o/p if The i/p is 3.8g (65)

b). what is The accloration if The digital o/p $(1001\ 0010)_2$ → $(146)_{10}$

9.49 * 1.5

$\frac{\text{analog} + V_{ref}^{+}}{\Delta V} = 146.$

analog + V_{ref}^{+} = 3.421 , analog = 0.421.



Range (15g ~ −15g)

Range O/P Sensor (−0.55 ~ 3.35 mA)

O/P Voltage (−0.11 V ~ 0.67 V)

$V_o = MV_i + \text{offset}$

$3 = 0.67M + \text{offset}$

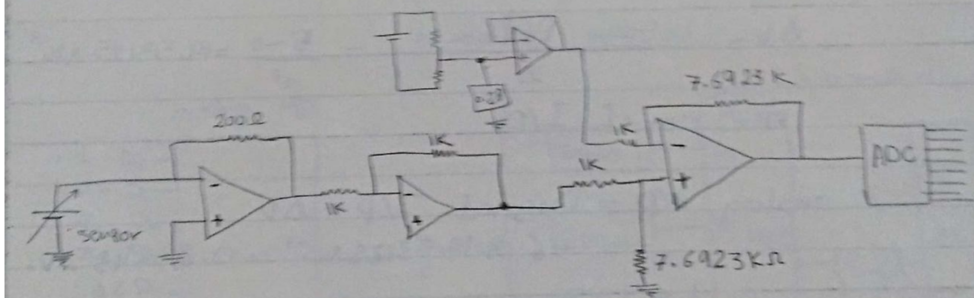
$-3 = -0.11M + \text{offset}$

$M = 7.6925$, offset = −2.1538

$V_o = 7.6923(V_{in} - 0.27999)$

$V_o = 7.6925\,V_{in} - 2.1538$

V_i	−0.11	0.28	0.67V
V_o	2.499	4.4×10^{-5}	3.00004



$\Delta V = 0.023437$

$$\text{Digital O/P} = \frac{\text{analog} + V_{ref}^{+}}{\Delta V}$$

$-3.8 \rightarrow \overset{114}{0.494\,mA} \sim \overset{0.906}{\underline{0.494}} \times 200 \sim \overset{181.2}{-98.8\,mV} =$

$\overset{0.1812}{-0.0988V} \rightarrow V_o = 7.6925\times(-0.0988) - 2.1538$ 95.5116

$V_o = \cancel{-2.913794}$, Digital O/P = $\cancel{3.67748}$
−0.76149 ~4

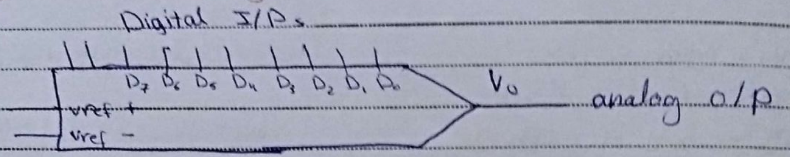
0000 0106

1011 1111

AgiP آجيب	INTERNAL NOTES	Date	N
FROM 26 /12/2019	TO EE462		Your Ref / Our Ref 12

Subject

Digital to analog Converter ▸



30 EX ▸ what is The Value of analog O/P if The digital I/P is $(10111 0)_2$ & The Voltage Reference is between $(0 \sim 5)v$?

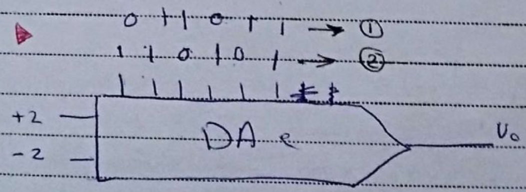
$$\Delta V = \frac{\text{Voltage Reference}}{2^n} = \frac{5-0}{2^8} = 19.53125 \times 10^{-3}$$

n = no. of I/P

EX ▸ analog O/P = Digital I/P * ΔV

$$= 46 \times 19.53125 \times 10^{-3} = 0.898435\ V.$$

31 EX ▸



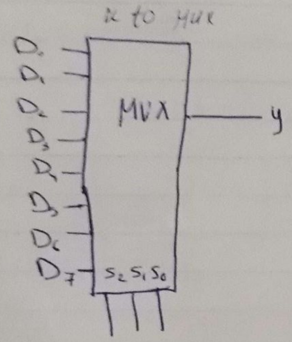
⊛ $\Delta V = \frac{4}{2^6} = 0.0625\ V$

① $= (27 \times 0.0625) - 2 = -0.3125\ V$

② $= (53 \times 0.0625) - 2 = 1.3125\ V$

(Digital I/P * ΔV) − Vref* = analog O/P

Data Selector

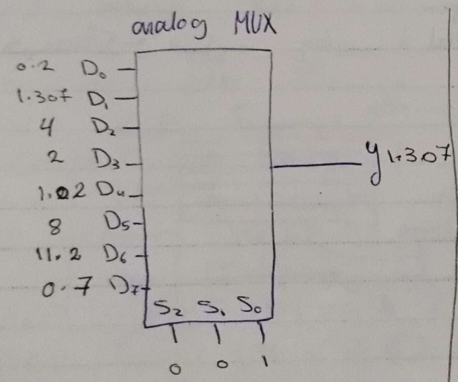


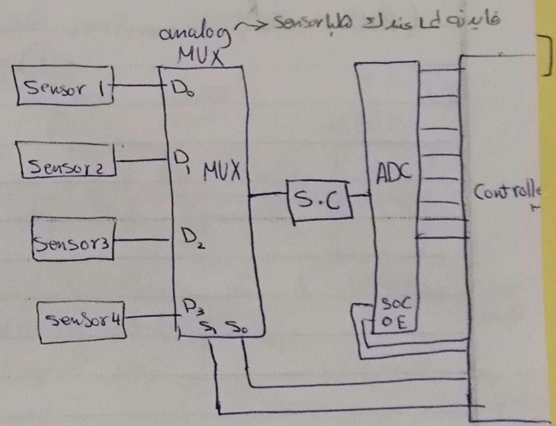
0 1 2 3 4 5 6 7
10110100

$S_2 S_1 S_0$
1 1 0

$y = D_6$ ☺

CMOS	TTL
0 ≙ Ground	5V ≙ 1
( )	(2 ~ 5.5)
5 ≙ 1	0 ≙ Ground
( )	(0 ~ 0.8)





AgiP آجيب

INTERNAL NOTES

Date

N

TO

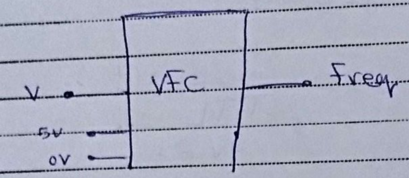
Your Ref

Our Ref

FROM

Subject

Voltage to freq Converter : (V.F.C) AD method (2)



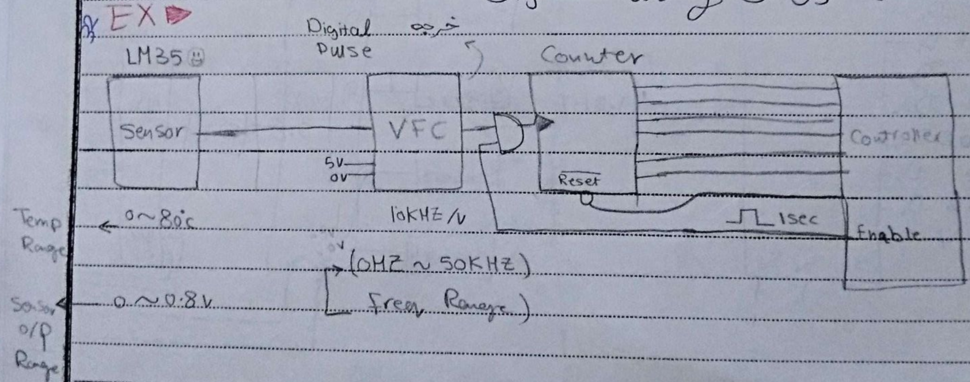
[10 KHZ /V] → Rate

(0V ~ 5V) → Voltage Range.

(0HZ ~ 50KHZ) → freq Range.

* وظيفته "أنْ" تحول من analog ل Digital.

EX ▶

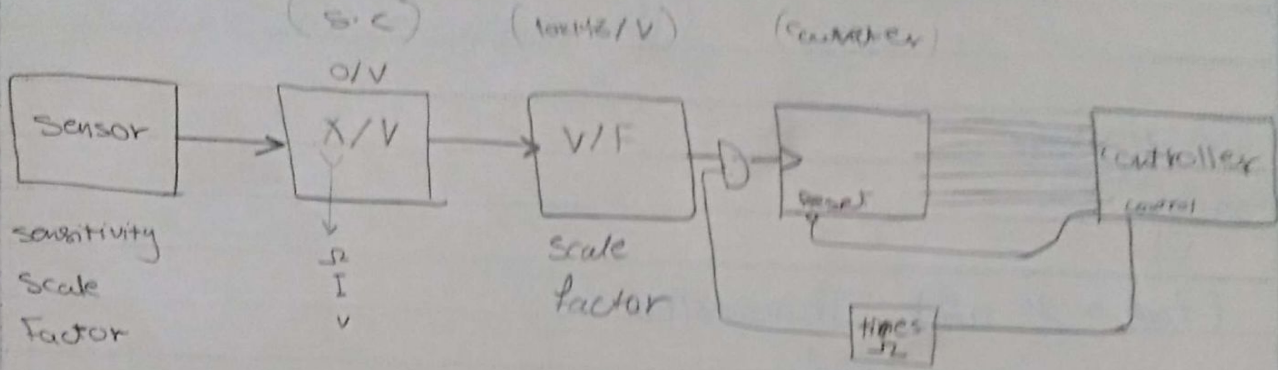


@ 20°C ⇒ 0.2V | $0.2V \times 10\frac{KHZ}{V} = 2KHZ$

@47°C 10mV/C°	5KHZ/V	duration (0.2 s)	what's o/p of Controller
@47°C → 0.47V	$0.47 \times 5\frac{KHZ}{V} = 2.35KHZ$	$0.2 \times 2350 =$ 470 Pulse	Exam Q

33 EX

20/1/2019 EE463 (13)



34 EX ▶ using Lm35 for the Range (30° ~ 90°) and using (V/f) which Scale factor (3KHZ/V) Calculate :

(a) Sensor o/P Range
V/f o/P Range
Counter o/P Range (using 0.2 s duration)

(b) what is the digital o/P of the Counter if the Temperature is 68.2 °

(c) what is the Value of Temprature if f.V digital o/P (Counter) is $(0011101101)_2 \equiv (237)_{10}$.

temp Range (30 ~ 90°)

Sensor o/P Range $(30 \times 10\frac{mV}{c}) \sim (90 \times 10\frac{mV}{c})$

(0.3 V ~ 0.9 V)

V/f o/P Range $(0.3V \times 3\frac{KHZ}{V} \sim 0.9V \times \frac{3KHZ}{V})$

(0.9KHZ ~ 2.7 KHZ)

AgiP آجيب	INTERNAL NOTES	Date	N
FROM	TO I wish I can sleep	Your Ref / Our Ref	

Subject

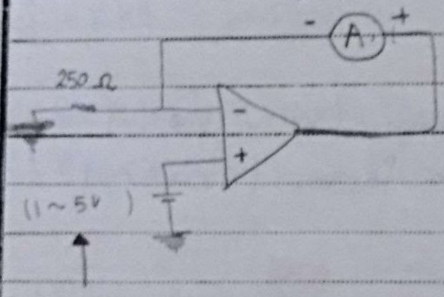
Counter o/P Range (0.9 KHZ X0.2 s ~ 2.7 KHZ * 0.2 s)

(180 pulse ~ 540 pulse)

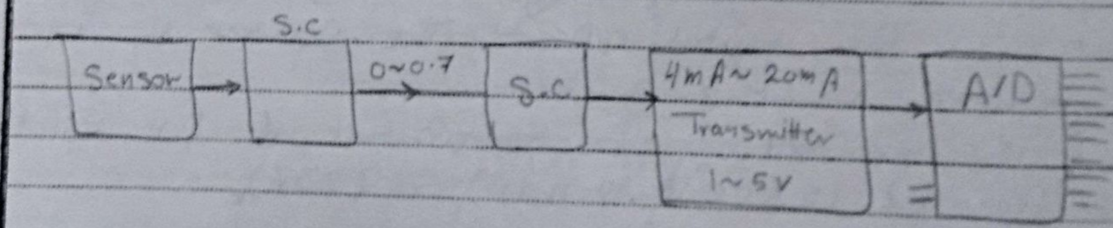
(b) 409.2 Pulse.

(c) 39.5°c.

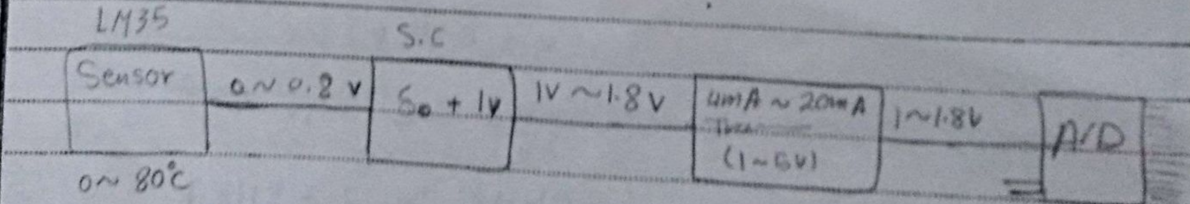
(4mA ~ 20 mA) Transmitter :



بيوصل الـ Data ك Current
طلب معلومة

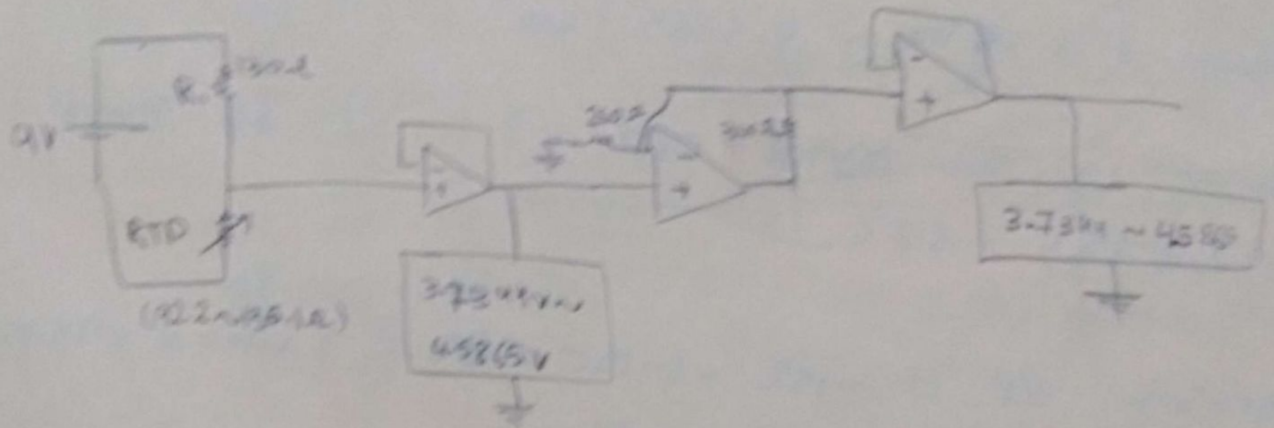


EX ▶



14 EE463 23/1/2019

* Ex: using RTD PT100 for Temp Range ($-20° \sim 90°$) in Voltage Devider with $R_1 = 130\Omega$ design Circuit to get The Temperature information for long distance to ADC wich Voltage Reference (± 2) volt



Solution: Temp Range ($-20° \sim 90°$)

- sensor o/p $[100\Omega + (0.39\,\Omega/°C \times -20°C)] \sim [100 + (0.39 \times 90)]$

$$(92.2\Omega \sim 135.1\Omega)$$

Voltage devider o/p Range

at $-20°$ $\rightarrow$ $V_o = 9 * \frac{92.2}{92.2+130} = 3.7344$ Volt

at $-90°C$ $\rightarrow$ $V_o = 9 * \frac{135.1}{135.1+130} = 4.5865$ Volt

$$-\left(\begin{aligned} -2 &= 3.7344\,M + \text{offset} \\ +2 &= 4.5865\,M + \text{offset} \end{aligned}\right.$$

$$4 = M$$

$M = 4.6943$

(1)

offset = -19.5308

$V_o = 4.6943\, V_i - 19.5308$

$V_o = 4.6943\,(V_i - 4.16055)$

V_i	3.7344	4.16055	4.5865
V_o	-2.009	0	1.99994

Range $(3.7345 \sim 4.5865)$ volt

(A) what is The digital O/P of if Temp is $-15°C$, $67°C$.

Solution (A):

sensor o/P at $-15°C = (-15C° \times 0.39 \frac{\Omega}{C°}) + 100\,\Omega = 94.15\,\Omega$

Voltage Devider $O/P = 9 \times \frac{94.15\,\Omega}{130 + 94.15} = 3.78022\,V$

Transmitter O/P = 3.78022 (because in The Range)

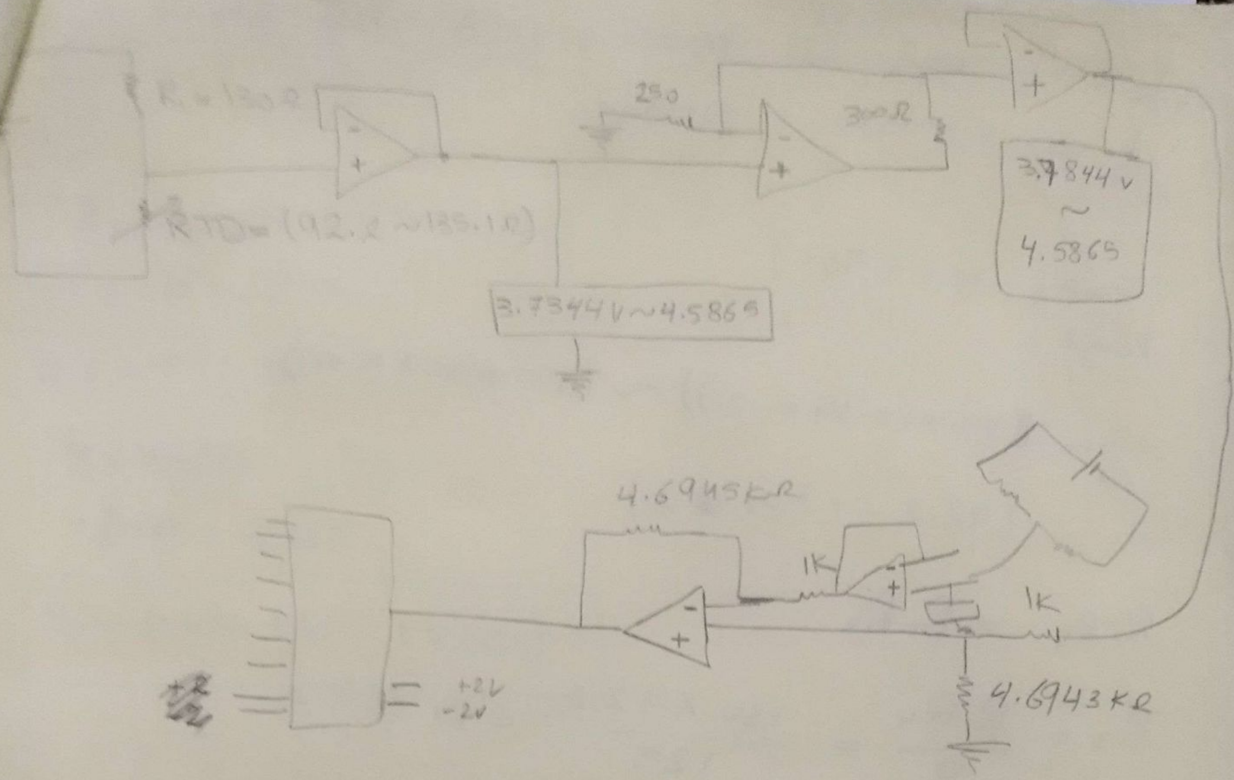
$S.C\ O/P = (3.78028 - 4.16055)\,4.6943 = -1.78509\,V$

$$\Delta V = \frac{2-(-2)}{2^8} = 0.015625\,V.$$

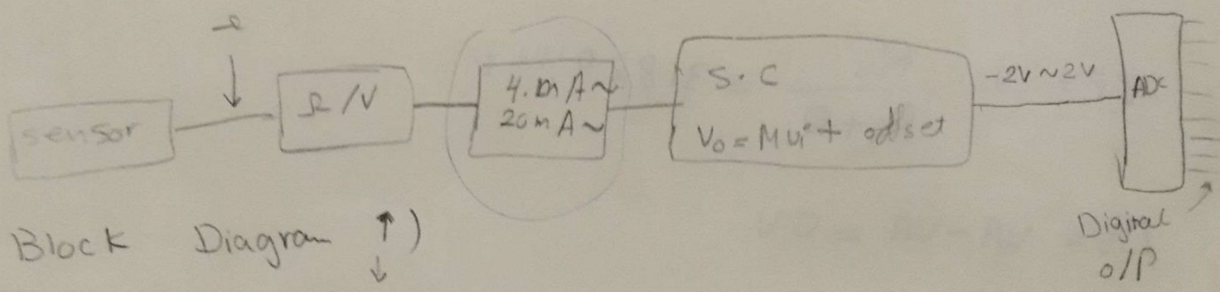
$$\text{Digital O/P} = \frac{\text{Analog i/P} + V_{out}}{\Delta V}$$

$$= \frac{-1.78509 + 2}{0.015625}$$

$= 13.75 \simeq 13 \rightarrow (0000\ 1101)_2$



(B)



(Block Diagram ↑)

ليرك علينا عكس بالعكس

الي مطلوب في (B)

3) EX: same as pervious eX but using wheaston bridge.

Solution:

Temp $(-20°c \sim 90°c)$
Range

Sensor o/p $((100+(0.39 * -20)) \sim (100+(90 \times 0.39))$

$(92.2 \sim 135.1\ \Omega)$

$R_1 R_4 = R_2 R_3$

$$R_3 = \frac{R_1 R_4}{R_2} = \frac{130 \times 92.2}{125} = 95.888\ \Omega$$

@ $-20°c$

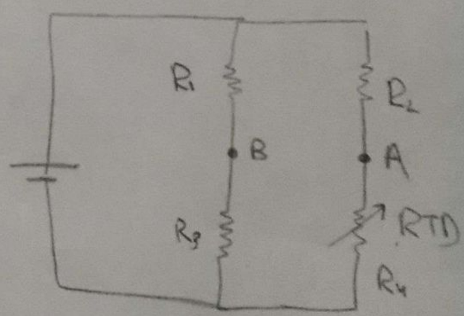
$$V_B = V_s \frac{R_3}{R_1 + R_3} = 3.82044\ V$$

$$V_P = V_s \frac{R_4}{R_4 + R_2} = 3.82044\ V$$

$\Delta V = V_A - V_B = 0\ V$

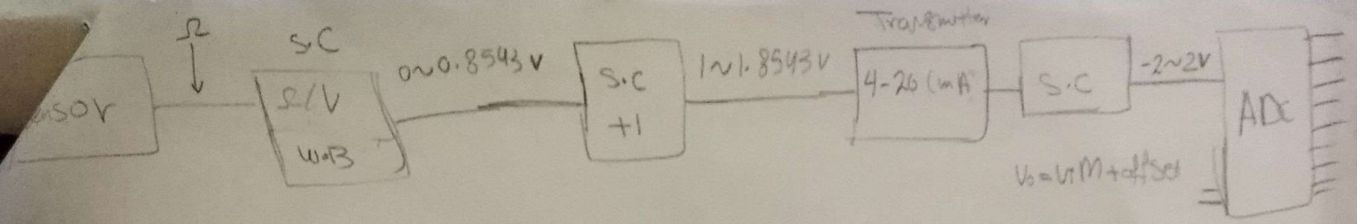
@ $90°c$

$$V_D = 9 \times \frac{135.1}{135.1 + 130} = 4.6747\ V$$



$\Delta V = 0.8543\ V.$

bridge Range $(0 \sim 0.8543V)$



$$2 = 1.8543\,M + \text{offset}$$

$$-2 = 1M + \text{offset}$$

$$4 = 0.8543\,M$$

$$M = 4.6821$$

$$\text{offset} = -6.682$$

$$\boxed{V_o = 4.6821\,(V_i - 1.42716)}$$

/ عدة wheaston قال نجيبها عالورقة

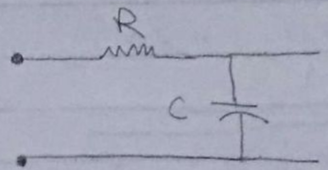
lect in yellow paper

27/1/2019 lect (15)

Filters:

- low pass filter:

$$F_C = \frac{1}{2\pi RC}$$



- signal freq: 1KHZ , Noise: 1MHZ ?

$F_C =$ 2KHZ or 5KHZ !!

$$V_o / V_i = \frac{1}{\sqrt{1 + \left(\frac{f_N}{f_c}\right)^2}}$$!!

38. EX ▸ The signal freq f_s is 1KHZ & undesired noise signal f_N 1MHZ. Design filter That attenuate the noise to 1% , and what is the effect of The filter on The desired signal ?

Solution:-

$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1 + \left(\frac{f_N}{f_c}\right)^2}}$$

$$0.01 \quad \frac{1}{\sqrt{1 + \left(\frac{10^6}{f_c}\right)^2}} \Rightarrow F_C = 10\,000.5 \text{ HZ}$$

The effect on the signal : $\frac{V_i}{V_o} = \frac{1}{\sqrt{1 + \left(\frac{F_s}{f_c}\right)^2}}$

AgiP آجيب | INTERNAL NOTES | Date | N

FROM | TO | Your Ref | Our Ref

Subject

$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1+\left(\frac{\cancel{1KHZ}}{10.5\ HZ}\right)^2}} = 0.99503 \Rightarrow \cancel{99\%}$$

99.503 % from the signal.

- let C = 0.1 μF

$$R = \frac{1}{2\pi * 10000.5 * 1\times10^{-6}} = 159.146\ \Omega.$$

$\boxed{160\ \Omega}$

★ قيم مقاومات التجارية 5% = E%

1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.8	2	2.2
2.4	2.7	3.0	3.3	3.6	4.3	4.7	5.1	5.6	6.2
6.8	7.5	8.2	9.1						

ومضاعفاتهم

when R = 160 Ω

$$f_c = \frac{1}{2\pi \times 160 \times 0.1\times10^{-6}} = 9947\ HZ.$$

$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1+\left(\frac{1000}{9947\ HZ}\right)^2}} = 0.99489 \Rightarrow 99.489\ \%$$

$\frac{1}{0.99489} = 1.005 \Rightarrow$ Gain ★ to Get back The Freq & all pervious value

when R =

$$Fc = \frac{1}{2\pi * 180 * 0.1 * 10^{-6}} = 8841.94 \text{ HZ}$$

$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1 + \left(\frac{1000}{8841.94}\right)^2}} = 0.99366 \Rightarrow 99.366\ \%$$

$$\text{Gain} = \frac{1}{0.99366} = 1.006$$ ✓

(16) EE463 30/1/2020

Signal freq 2KHZ, Noise 110 KHZ at ① [1% Noise attenuation.]

$$0.01 = \frac{1}{\sqrt{1 + \left(\frac{110 \text{ KHZ}}{Fc}\right)^2}} \Rightarrow Fc = 1.1 \text{ KHZ}.$$

effect on the Signal. $\frac{V_o}{V_i} = \frac{1}{\sqrt{1 + \left(\frac{2 \text{KHZ}}{1.1 \text{KHZ}}\right)^2}} = 0.4819$

which is very bad. $\Rightarrow 48.19\ \%$

② • up to 5% Noise attenuation.

AgiP آجيب | INTERNAL NOTES | Date | N

Your Ref

Our Ref

TO

FROM

Subject

$$0.05 = \frac{1}{\sqrt{1+\left(\frac{110KHZ}{fc}\right)^2}} = 5.5KHZ$$

effect on the signal = 0.939 which is better

علام تتكلم !!

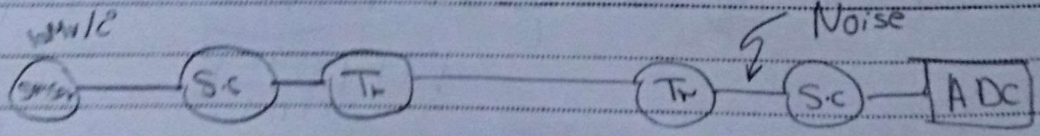
③ up to 7% Noise attenuation

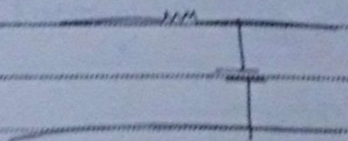
$$0.07 = \frac{1}{\sqrt{1+\left(\frac{110KHZ}{fc}\right)^2}} = 7.71KHZ$$

effect on the signal = 96.8%

$$Gain = \frac{1}{0.968} = 1.033$$

* when Noise attenuation up to 10%, $f_c = 11KHZ$, effect = 98.38%

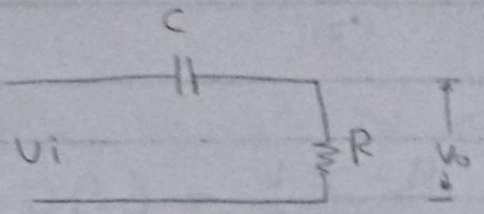




{3 itreation in exam}

- High pass filter ▸
يدي ال fc أعلى منه ، و low عكس [$F_s > F_c$]

$$\frac{V_o}{V_i} = \frac{F/F_c}{\sqrt{1+\left(\frac{F}{F_c}\right)^2}}$$



EX ▸ Noise 50 HZ, Signal 1KHZ (Select / design) The Filter Circuit & Calculate The effect on The Signal.

Solution :-

$$0.01 = \frac{50\,HZ/F_c}{\sqrt{1+\left(\frac{50}{F_c}\right)^2}} = 5\,KHZ \rightarrow [\text{at } 1\%]$$

which is very bad because F_c is higher Than The Signal.

[at 5%]

$$0.05 = \frac{50\,HZ/F_c}{\sqrt{1+\left(\frac{50}{F_c}\right)^2}} = 998\,HZ$$

[effect on The Signal
70%

AgiP آجيب	INTERNAL NOTES	Date	N
FROM	TO	Your Ref / Our Ref	

Subject (17) 3/2/2020

$R = \frac{9 - 2.1}{10mA} = 690\ \Omega$ [Green = 2.1V]

$R \simeq 680\ \Omega \rightarrow$ (أقرب قيمة / الأكثر شيوعاً) [use 10mA] ✓

10.14mA max 20mA

Q1 (18) EXam 1 ? 6/2/2020

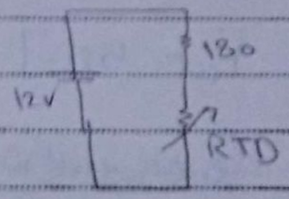
B

Temp = ($-15°C \sim 180°C$)

Sensor o/P Range = $[200 + (-15 \times 0.39)] \sim [200 + (180 \times 0.39)]$

$= 194.15\ \Omega \sim 270.2\ \Omega$

$V_{o\,min} = 12 \times \frac{194.15}{194.15 + 180} = 6.22691\ V$



$V_{o\,max} = 12 \times \frac{270.2}{270.2 + 180} = 7.20218\ V$

Voltage Devider o/P ($6.22691 \sim 7.20218$)

Scale factor = $5KHZ / 1.2\ V \Rightarrow 4.1667\ \frac{KHZ}{V}$

VFC output Range ($6.2269\ V * 4.1667\ \frac{KHZ}{V}$

$\sim 7.20218\ V * 4.1667\ \frac{KHZ}{V}$)

$(25.945458\ KHZ \sim 30.008875\ KHZ)$

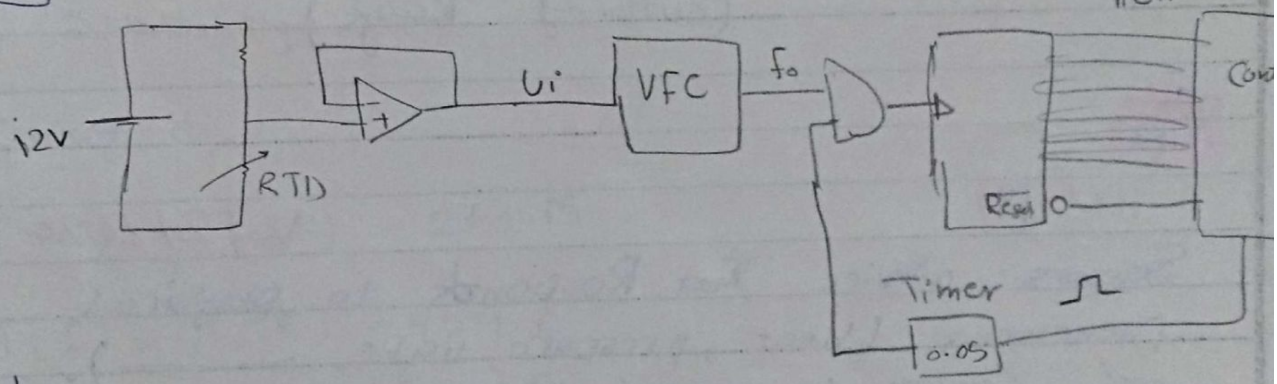
20 Sample / Sec $\longrightarrow$ duty Cycle $= \frac{1}{20} = 0.05$ Sec

- Counter o/p Rage : $\rightarrow$ [redacted]

$(0.05 \times 25.9454\ KHZ \sim 0.05 \times 30.00875\ KHZ)$

$(1297.2729$ pulse ~ 1500.44375 pulse$)$

$\boxed{A}$



$\boxed{C}$

@ 112°C

Sensor o/p : $(112°C \times 2.39\ \frac{\Omega}{°C}) + 200 = 243.68\ \Omega$

$$VD\ o/p = 12 \times \frac{243.68}{243.68 + 180} = 6.9018\ V$$

VFC o/p $= 6.9018 \times 4.16667 = 28.7575$

AgiP آجيب	INTERNAL NOTES	Date	N

FROM	TO	Your Ref / Our Ref

Subject

Counter o/p = 28.757 KHZ X 0.05 sec

$= 1437.877 = (1437)_{10}$

$(\quad 10110011101)_2$

d) $(1111101000)_2 \rightarrow (1000)_{10}$

which is less than The min Range (out of Range)

Q2

lect (49)

10/2/2020

Sensors: adevice That Responds to physical phenomena (heat, pressure, light, ———). and Convert to signal Relating to The quantity being measured.

Sensors

continuous

LM35 $10 mV / c^\circ$

$0 c \rightarrow 0 V$

$32 c^\circ \rightarrow 320 mV$

discrete

الواحدة الا صحيح او خاطئ

(ON / off)

1* passive Sensor : R, L ماي لازم احتاج تغذية ز ي

2* active sensor : solar sell بولد تغذية زي

* Sensor Selection :

o/p
1- Range , 2- cost , 3- permability , 4- Rebliability
5- linearity , 6- Response time , 7- sensitivity
8- power consumption , 9- size , 10- Temp Range
11- Stability, 12 -

* Convert eq :

$$T(c^\circ) = T(K) - 273.15$$

$$T(f^\circ) = T(R) - 459.6$$

$$T(f^\circ) = \frac{9}{5}\, T(C^\circ) + 32$$

	Rankine	Fahrenhiet	Celsius	Kelvin
	R°	F°	C°	K°
درجة غليان	672	212	100	373
درجة تجمد	492	32	0	273

Scanned by CamScanner

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INTERNAL NOTES

Date

N

FROM

TO

Your Ref

Our Ref

Subject

* Temperature:

PTC T↑ o/P ↑

NTC T↓ o/P ↓

PT 100 ~> sensitive 3.9 C°/Ω

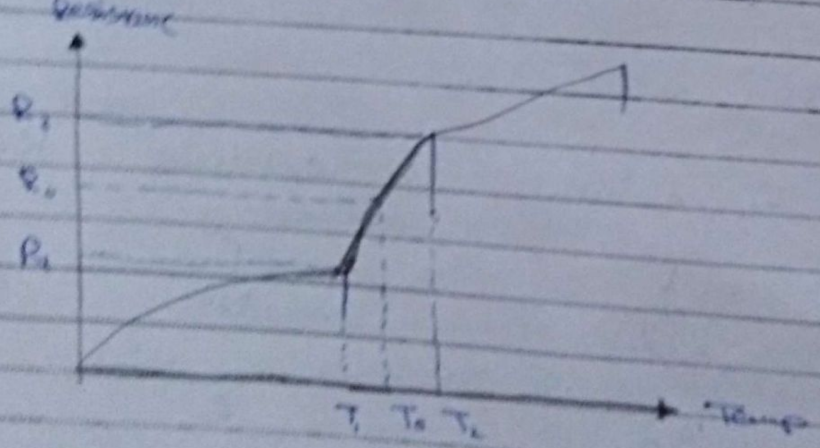
(0.5 ~ 5)s ⟺ RTD

(-100 ~ 135) بلاتين

(-180 ~ 300°c) نيكل

مدى Rage

* if my sensor not linear :



linear approximation method ▸

$$R(T) = R(T_0)(1 + \alpha_0 \Delta T)$$

$$\Delta T = T - T_0$$

$$\alpha_0 = \frac{1}{R T_0} \frac{R_2 - R_1}{T_2 - T_1}$$

$R(T)$ approximation of Resistance at Temp T

$R(T_0)$ " " " T_0

α_0 - fractional change in Resistance per degree of Temp.

lect(20) 13/2/2020

Ex: a Sample of metal Resistance versu Temperature has The following measured values.

	T(F°)	R(Ω)	
T_1	60	106.0	R_1
	65	107.6	
	70	109.1	
T_0	75	110.2	R_0
	80	111.1	
	85	111.7	
T_2	90	112.2	R_2

AgiP آجيب	INTERNAL NOTES	Date	N
FROM	TO	Your Ref / Our Ref	

Subject

Find The linear approximation of The Resistance Versus Temprature between 0 & 90°F.

$$\alpha_0 = \frac{1}{R(T_0)} \left(\frac{R_2 - R_1}{T_2 - T_1} \right)$$

$$\alpha_0 = \frac{1}{110.2} \left(\frac{112.2 - 106.0}{90 - 60} \right) = 1.8753 \times 10^{-3}$$

$T = 61°F$

$$R(T) = R(T_0) \left[1 + \alpha_0 \Delta T \right]$$

$$= 110.2 \left[1 + 1.8753 \times 10^{-3} (61 - 110.2) \right]$$

$$= 107.3068 \ \Omega$$

$T = 65°F$

$$R(T) = 110.2 \left[1 + 1.8753 \times 10^{-3} (65 - 110.2) \right]$$

$$= 108.1334 \ \Omega \rightarrow$$ مفروض تطلع 107.6

$T = 87°$

$$R(T) = 112.67 \ \Omega$$

نسبة الخطأ عند 60°F $\frac{107.1 - 106}{107.1} = 1\%$ نسبة الخطأ !!

quadratic approximation. method :

$$R(T) = R(T_0)\left[1 + \alpha_1 \Delta T + \alpha_2 (\Delta T)^2\right]$$

$$\Delta T = T - T_0$$

$$\alpha_1 = \frac{1}{R(T_0)}\left(\frac{R_2 - R_1}{T_2 - T_1}\right)$$

Same as pervious Ex using quadratic :

$$R(T) = R(T_0)\left[1 + \alpha_1 \Delta T + \alpha_2 (\Delta T)^2\right]$$

$$112.2 = 110.2\left[1 + \alpha_1 (90 - 75) + \alpha_2 (90-75)^2\right]$$

$$106.0 = 110.2\left[1 + \alpha_1 (60 - 75) + \alpha_2 (60 - 75)^2\right]$$

0.01814

$$0.018 = \left[\alpha_1 15 + 225 \alpha_2\right]$$

−0.03811

$$-0.038 = \left[\alpha_1 15 + 225 \alpha_2\right]$$

1.875×10^{-3} $\quad$ -44.37×10^{-5}

$$\alpha_1 = 1.8667 \times 10^{-3}, \quad \alpha_2 = -4.444 \times 10^{-5}$$

$T = 61 F^\circ$

106.348 Ω

$R(T) = 106.36\ \Omega$

$T = 65 F^\circ$ $\quad$ 107.644 Ω

$R(T) = 107.65\ \Omega$

$T = 87 F^\circ$

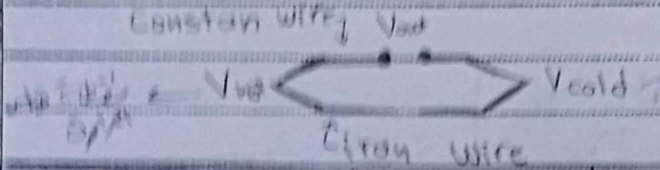
111.777 Ω

$R(T) = 111.96\ \Omega$

Agip آجيب	INTERNAL NOTES	Date	N
FROM	TO	Your Ref / Our Ref	

Subject Lect (21) 463 20/2/2020

Thermo Couple :
(الازدواج الحراري)



" لازم نستخدم جدول "

Junction material	Range (C°)	nominal sensitivity (MV/C°)	Type
* Platinum 6%/Rhodium Platinum 30%/Rhodium	38 ~ 1800	7.7	B
Tungsten 5%/Rhenium " 26%/ "	0 ~ 2300	16	C
Chromel – Constan	0 ~ 982	76	E
Iron – Constan	0 ~ 760	55	J
Chromel – Alumel	-184 ~ 126	39	K

1* Controlled Temperture reference block.

2 Reference Composition circuit

3 Software Reference Correction.

↑ طرق ال Composition *

* خرج المحس ب MV

0 5 10 15 20 ~ ...

-0 → الفولتات يدل بالسالب

+0 → " " بالموجب

* عند مرجعية 0°C

J- Type

25°C = 1.28 mV

-30°C = -1.48 mV

675°C = 37.6 mV

-99°C = -4.42 mV

-125°C = -5.61 mV

-55°C = -2.66 mV

$$T_m = T_L + \left[\frac{T_H - T_L}{V_H - V_L}\right](V_m - V_L)$$

$$V_m = V_L + \left[\frac{V_H - V_L}{T_H - T_L}\right](T_m - T_L)$$

لما يكون الرقم مش موجود في الجدول interpolation

EX: a Voltage of 23.72 mV is measured with K Thermo Couple, find The Tempeture of measurment Junction:

$V_L = 23.63$, $T_L = 570°C$ } أصغر من V_m, T_m

$V_H = 23.84$, $T_H = 575°C$] أكبر من V_m, T_m

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INTERNAL NOTES | Date | N

FROM | TO | Your Ref | Our Ref

Subject

$T_m = 572.1429°c$ ✓ using equation

EX: Find the voltage of Type J Thermoc[ouple] with Zero degree reference if shunt Temp is $-172°c$

$V_m = -7.18\ mV$.

$T_m = -172°c$

$V_H = -7.12\ mV$

$V_L = -7.27\ mV$

$T_H = -170°c$

$T_L = -175°c$